4. Dr. Weininger's comments about the Thomann Report are set forth in Exhibit A hereto.

5. In March, 1981, Mr. Edward H. Brown, Jr. was an employee of the U.S. Fish & Wildlife Service. He was employed at the Great Lakes Fishery Laboratory in Ann Arbor, Michigan.

6. At this time Dr. Brown was generally familiar with information and studies concerning the Lake Trout in Lake Michigan.

7. In March, 1981, Mr. Brown authored a paper entitled "A Background Discussion of the Lake Michigan Committee's Goal for Lake Trout Rehabilitation." This paper was presented at the Great Lakes Fishery Commission, Lake Michigan Committee Meeting in Milwaukee, Wisconsin.

8. Mr. Brown presented this paper in his capacity as an employee of the U.S. Fish & Wildlife Service.

9. Larry Kamer has made no formal survey to determine the level of public interest regarding the presence of PCB's in Waukegan Harbor or North Ditch, or on the property of OMC.

10. Any testimony of Larry Kamer regarding any alleged "restricted use and enjoyment" of Waukegan Harbor by the public is not based on any scientifically designed and executed survey or study.

11. Any testimony of Larry Kamer regarding any alleged "restricted use and enjoyment" of Waukegan Harbor by the public is not based on any study or survey of any statistically representative sample of the public.

BAF7-G/

12. Any testimony of Larry Kamer regarding any alleged "restricted use and enjoyment" of Waukegan Harbor by the public is not based on information obtained by using a standard questionnaire or list of questions.

13. Any testimony of Larry Kamer regarding any alleged "restricted use and enjoyment" of Waukegan Harbor by the public is not based on any information or observations that Mr. Kamer regularly, systematically and completely recorded.

14. Mr. Kamer has no records that identify the persons with whom he had discussions regarding their "use and enjoyment" of Waukegan Harbor.

15. Mr. Kamer made no contemporaneous notes or records regarding any of his observations relating to the "use and enjoyment" of Waukegan Harbor by the public.

16. Mr. Kamer has no contemporaneous notes or records regarding any of his observations relating to the "use and enjoyment" of Waukegan Harbor by the public.

17. Mr. Kamer has no contemporaneous notes or records regarding any conversations or discussions with people who regularly use or have used Waukegan Harbor concerning their use and enjoyment of the Harbor.

Bruce A Featherstone

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James H. Schink
Bruce A. Featherstone
KIRKLAND & ELLIS
200 East Randolph Drive
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(312) 861-3260

Attorneys for MONSANTO COMPANY

DATED: January 6, 1983

CERTIFICATE OF SERVICE

BRUCE A. FEATHERSTONE hereby certifies that on January 6, 1983, he caused a copy of THIRD-PARTY DEFENDANT MONSANTO COMPANY'S FOURTH SET OF REQUESTS FOR ADMISSION TO PLAINTIFF UNITED STATES to be hand delivered to all counsel on the attached Service List.

Bruce A. Featherstone
Attorney for MONSANTO COMPANY

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Assistant Attorney General
Environmental Control Division
188 West Randolph Street - Suite 2315
Chicago, Illinois 60601

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

DATE: 2/26/81

SUBJECT: Additional Review of Hydro Qual Report

FROM: John F. Paul, Ph.D.
Large Lakes Research Station

John Paul

TO: Edward DiDomenico
Enforcement Division, Region V

Find enclosed one additional review of the Hydro Qual report. This was done by Dave Weininger at the Duluth laboratory.

Encl.

EXHIBIT A

EPA Form 1320-6 (Rev. 6-72)

US 51457

CONFIDENTIAL

Review of

"Mathematical Modeling Estimate of Environmental Exposure to PCB Contaminated Harbor Sediments of Waukegan Harbor and North Ditch" by HydroQual, Inc"

D. Weininger February 17, 1981

al Impressions

The HydroQual report (February 1981) presents the results of mathematical :ling of PCB in Waukegan but provides insufficient detail concerning many ects of the modeling to permit judgement on the scientific merit. The work ,ch was reported therein may have been good, state-of-the-art scientific alyses, but the report only hints that the analyses were sound. Virtually very section "talks about" the work performed while leaving the analysis unexplained nd its validity undemonstrated. The technical approaches are not defined in ·ny tail, the data and results are not presented so that they may be verified or reproduced, and the figures (of which there are many) do not particularly illuminate their subjects.

While this confusion is unacceptable in a scientific paper, it is possible that this is an excellent report to the court from an expert witness. The report contains good sounding science and is written by a well-known modeler. The aspects which I found frustrating as a reviewer, such as the lack of a reproducible set of data and tables of intermediate results, may very well increase its legal impact by discouraging challenges in court. The following review will be limited to a "review for basic technical content" which is what was requested (and in any case, is all that I am even partially qualified for).

References are limited to figure titles and section names because the draft I received had unnumbered pages.

US 51459

The following is a section by section review of "Mathematical Modeling Estimate of Environmental Exposure due to PCB-Contaminated Harbor Sediments of Waukegan Harbor and North Ditch" by R. V. Thomann, et al. of HydroQual, Inc. This review is based on a draft dated February 1981.

My first comment is that the title could be shortened and made more explicit e.g., "Mathematical Modeling of PCBs in Waukegan Harbor and OMC North Ditch Sediments". At least the first occurrence of the word "Harbor" should be removed in the present title.

The introduction (Section 1) is informative, short, and adequate. The first figure, "Location of study area" could be removed without detriment.

The conclusions (Section 2) succinctly summarize those drawn in the text. A review of conclusions is included with the review of each section below. Two points will be discussed here, however. Conclusion 1a is out of place in this section and more properly belongs in a methodology discussion. Conclusions 6a, b, 7a, b, and c are weakened by a failure to account for the PCBs known to be on OMC property ("under the parking lot") and past dredging of the harbor (some spoils deposited on shore and some offshore).

The recommendations (Section 3) follow pretty much logically from the report, from a modeler's point of view. Recommendations 1, 2, and 3 all propose modeling efforts with a view to refining our historical perspective, the importance of which is not clear. From the perspective given in this report, the answer to #4 must be "a long, long, time." If this is not the case, no clue is given in the text. Recommendation 5 is clear and should be supported widely.

Section 4, an estimate of the mass of PCBs in the Harbor and Ditch, is very deficient in its technical description. Assuming the sediment PCB data was divided into geographic regions (segments) and analyzed individually, it is important to show the results of these calculations. The credibility of these very important estimations is very low since the most elementary statistics (such as the total number of data and the number of data per segment) are not given. Inclusion of a table which summarizes the segment and depth PCB distributional statistics along with an explanation of how the "best", "high", and "low" estimates were combined to form the final estimates would add a lot to the credibility of this section.

While it is not possible to verify the results of Section 4 from the information presented, it is possible to get an estimate of the accuracy which can be expected. To this end, the data on the figure labeled "Surface sediment total PCB concentrations" was graphically obtained and submitted to a simple linear regression (see attached). Greater than 70 percent of the total variance of log [PCB] was explained by "distance from harbor mouth". An even better relationship might be expected if "distance from Slip #3 discharge" was used.

If 95 percent of the PCB in Waukegan Harbor is in Slip #3, then it is reasonable to assume that the uncertainty of a total harbor PCB estimate will be close to the uncertainty in the estimate of the [PCB] in Slip #3. The calculation of the regression statistics is attached. If we take Slip #3 to be at 1550 m from the harbor mouth, we expect the average PCB concentration to be 1506 ppm. One standard error on this prediction either way gives high and low estimates (analogous to the report) of 2036 ppm (+36%) and 1115 ppm (⁻26%). Unless the deeper sediments are more concentrated or more variable than the surficial sediments worked here, this should be the approximate confidence level of the final result.

The results in the report show more uncertainty than the above (+66% and ⁻63%). The most likely cause of this is that small values for N had to be used due to the segmented approach. Similar standard errors (+65%, ⁻40%) were found when simulating the Slip #3 concentration calculation using only the 12 values with distances >1500 m. All information can be used for the mean concentration calculation even if the integration procedure is segmented for convenience. Another possible error may have occurred when combining PCB masses in the segments to calculate the total sum. Although "high estimates" and "low estimates" sound like additive things, they are based on standard errors and are not additive. Failure to account for this by converting to combined variance would expand the uncertainty band considerably.

One final note on Section 4 is that the second handwritten equation must be incorrect. The right side of the equation is missing an exponentation, I think, and unless I'm missing the mark entirely, the left side should be $\hat{\sigma}_{\ddot{\mu}_r}$, not $\hat{\sigma}_{\mu_r}$.

US 51461

Section 5, which briefly describes data collection efforts, seems adequate for the purposes of this report.

Water Quality Data Analysis, Section 6, is very figure-heavy (15pp) ard analysis/ discussion shy (only 3 1/4 pp). The discussion of the Harbor water quality data, which is basically descriptive, would be enhanced by removal of Figures 17 (appears earlier), 19, 20, and 21; inclusion of a table summarizing the suspended solids data; combination of Figures 22 and 23; and clarification of Figure 24. The data seem very good. A good point was made with Figure 24. The work on the Ditch was quite well done, particularly tracing the rainfall event. The quoted loadings seem both reasonable and defensible although based on a minimum adequate data set.

Only an overview, and not a critical review, will be attempted for Sections 7, 8, and 9, since the physical modeling of water is not my expertise. There were several points, probably minor, which I found disturbing. The first is that horizontal exchange was reported in flow units (m^3/da) rather than "eddy diffusivity" units (m^2/da); this seems awkward for a system which is almost entirely dispersive. Due to this unconventional parameterization, the horizontal exchange figure is difficult to fathom. An explanation of where the other length dimension fits in would be appropriate. The second point is that Cl^- gradients (Fig. 28) are apparently thought to be due to significant steady-state exchange with the lake via the harbor mouth. Were mixing coefficients estimated from estimated flux, visa-versa, or neither? This is not entirely clear. Another, perhaps obvious, point is that the sharp May decrease in Cl^- seems to argue against the steady-state assumption. The explanation given is that a "flush-out" occurred between steady-state periods; other possible explanations are not given entirely adequate acknowledgement.

The seemingly low PCB loss from the harbor to the lake is not only probably correct, but quite defensible. Even using all high estimates in a conventional dispersive model:

[PCB] gradient at h. mouth	=	0.1 ng/l/100m = $.1 \times 10^{-6}$ kg/$m^3$100m.
horizontal eddy diffusivity	=	10,000 cm^2/sec,
harbor mouth cross-section	=	100m x 10m = 1000 m^2,

the calculated flux under these assumptions is 31.5 kg/yr. It's easy to believe that scaling down to realistic values produces a value < 10 kg/yr.

dredges: [illegible]
& therefore PCB
loss

The analysis of bioaccumulation of PCBs by small fish in Waukegan Harbor (Section 10) is rather cursory, presumably due to the small amount of data available. The bioaccumulation factor approach used seems to be adequate for a rough approximation of the process. The conversion from bioaccumulation to total fish PCB concentration was apparently done by a simple arithmetic application of a fish water content of approximately 85 percent. This could be explained in the interest of clarity.

The conclusions of Section 10 appear justificable. Some of the terminology used is unnecessarily imprecise; the estimated 5-100 ppm "PCB body burden" is actually a "whole fish PCB concentration" (body burden usually means the total masses of a substance in a fish). It should be noted that the estimated fish PCB levels are on a whole fish basis whereas the FDA action levels to which they are compared are based on the edible portion only. This consideration does not substantially affect the conclusions drawn.

If PCB data were available for fish forage organisms, it might be possible to considerably strengthen the PCB bioaccumulation model. Since most of the fish PCB load is thought to accumulate via the ingestive pathway, it would be appropriate to estimate fish PCB levels based on the levels in their prey by using gross assimilation efficiency considerations. The approach used is appropriate in the absence of such data.

An effort was obviously made to clearly explain the logic behind the calculations of PCB losses and fluxes to Lake Michigan in Section 11. As a result, the conclusions drawn are straightforward and appear to be justifiable in the context that they are presented.

There are two factors which seem to have been either overlooked or omitted in this section. The first is that there are known to be substantial deposits (and therefore losses) of PCB on OMC property which are not in the harbor or the ditch. The second is that substantial amounts of presumably high PCB sediment have been removed by dredging from the outer and middle harbor, some of which was disposed of on land and some in Lake Michigan. Although there is a poor data base from which to estimate these deposits, an effort should be made to integrate such estimates into the considerations presented. Both factors will affect (upward) the percentage of PCB usage accounted for. Accounting for the dredge spoil deposition would increase the estimates for "PCB discharge to Harbor" and "Total PCB discharge to Lake Michigan". It should be emphasized that omitting these considerations does not seriously affect the validity of the conclusions as long as they are viewed in the context of their obvious limitations.

Section 12, which assesses the significance of the Harbor and Ditch discharges, comes to the conclusion that although 50-90 percent of the total PCB load to Lake Michigan in the past was due to flux through the Harbor/Ditch system, this figure is now less than 1-2 percent. The arguments behind this conclusion seem logically derived from the rest of the report. Estimates of total PCB loading to Lake Michigan are near the widely accepted values. The 1-2 percent estimate of current PCB contributions is somewhat misleading since the Waukegan PCB load is essentially being compared with the atmospheric load over the whole of Lake Michigan. Considering the Lake's hydrology, it would seem much more reasonable to limit such comparisons to the loading of Lake Michigan's southern basin only. The effect of this would be to increase the current percentage load estimate; in any case, the estimate would be small (<5%).

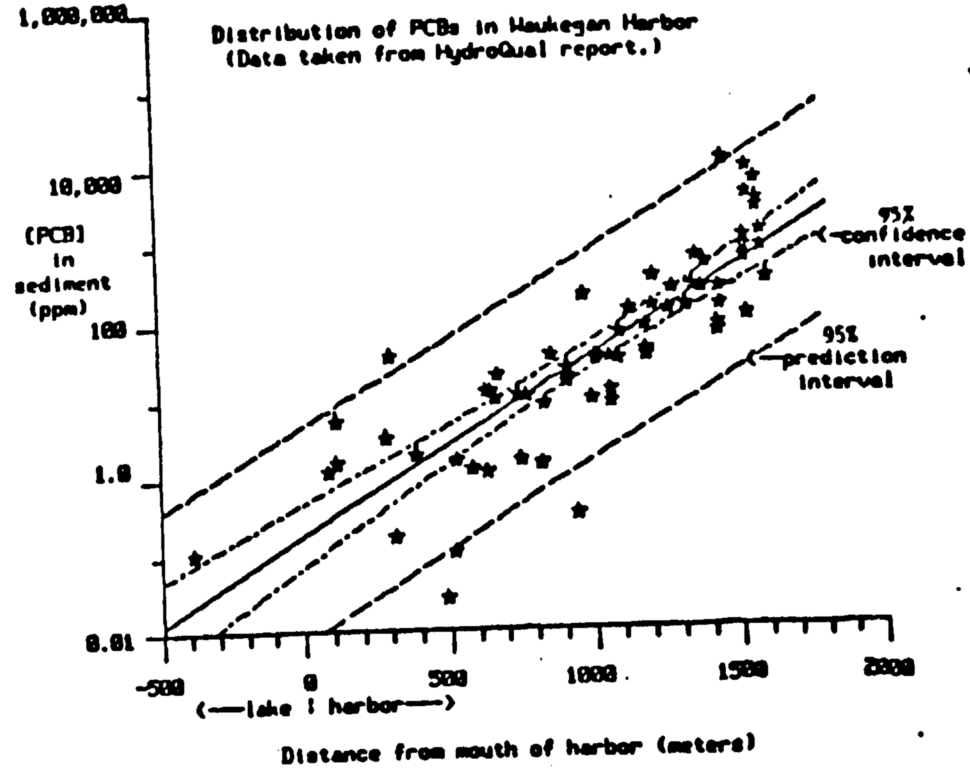
The final section (13) discusses the significance of harbor dredging. Two conclusions about PCB flux are drawn; dredging the Harbor to levels of 10-100 ppm would probably eliminate the flux of PCB from the Harbor to the lake and dredging to lower levels would not be effective for further reductions of loading. Assuming the mathematical model was correctly applied, these conclusions are warranted.

In my opinion, the final conclusion regarding decreases in resultant fish concentrations is far less justifiable. The predicted fish concentrations of course parallel the predicted decreases in water PCB concentration; the bioaccumulation model used is simply a ratio of these two levels. Because this ratio seems to work with existing conditions does not mean that the ratio provides an adequate predictive model. It was mentioned in Section 10 that 75 percent of the fish PCB level was attributed to ingestive (food-chain) uptake and 25 percent to direct uptake from water. Aside from the likelihood that dissolved PCBs are more available than particulate PCBs, it might be reasonable to expect one quarter of the current fish levels will follow the expected decrease in water PCB concentration downward. Does this mean that the ingestive PCB uptake should follow proportionally? A simple bioaccumulation model obviously indicates that it would. But look at the result: fish are predicted to have a level of near 5 ppm wet (ca. 30 ppm dry) when the sediment level is 100 ppm. Since benthic invertebrates and insects comprise a significant portion of the diet of a small fish and most of the fish PCB load is ingested, this doesn't leave a lot of room for food chain biomagnification. The predicted system appears unrealistic, indicating that in this case the simple bioaccumulation model may have been pushed too far. It might be argued that all system components levels should rise and fall proportionally--except that there is no reason to assume that biomagnification is an equilibrium process; and much evidence to the contrary.

In summary, the authors seem to have done a good job of bringing together a large amount of data and drawing a number of relevant and defensible conclusions. My main objection to the report is that it is sorely lacking in technical explanation. Much of this lack can be justified on the basis of a desire for simplicity, but in my opinion, critical pieces of information were too often left out. If technical credibility is of primary importance, I would recommend that the text of this report be reworked with the goal of providing clearer explanations.

PCBs in Waukegan Harbor
Data taken from figure in HydroQual report.
Distance = meters from Harbor mouth
Conc. = $\log_{10}$ [ug PCB / g dry sediment]

Distance	Conc.	Distance	Conc.	Distance	Conc.
1549.350	3.779	1518.363	3.907	1439.487	4.026
1554.904	3.408	1521.100	3.593	1557.801.	- 3.511
1570.478	3.099	1570.478	2.903	1509.912	3.021
1509.912	2.903	1509.912	2.779	1346.526	2.790
1377.513	2.607	1332.441	2.414	1204.268	2.532
1266.242	2.378	1198.634	2.161	969.840	2.326
1123.983	2.120	1587.380	2.491	1422.505	2.378
1425.402	2.161	1518.363	2.027	1419.768	1.914
1419.768	1.837	1366.245	2.378	1312.722	2.161
1253.565	2.120	1100.323	1.528	1180.323	1.605
1004.545	1.502	1057.784	1.523	1056.375	1.090
1056.375	0.936	994.401	0.907	900.482	1.399
908.482	1.348	908.402	1.206	900.402	1.219
939.470	-0.506	819.747	0.142	631.008	0.050
746.505	0.109	770.450	1.028	739.463	1.028
831.015	0.910	856.368	1.543	669.038	1.296
645.093	1.090	631.008	1.090	661.995	0.987
500.302	0.036	520.180	0.194	1011.303	1.554
1011.303	1.502	1176.098	1.914	1091.508	1.021
302.828	1.559	112.680	0.730	284.517	0.508
305.929	0.276	87.327	0.070	112.680	0.189
312.687	-0.774	515.511	-0.965	485.933	-1.500
-388.746	-0.980				



$n=67$ $\bar{X}=1002.$ $\bar{Y}=3.614$ $a=-1.712$ $b=0.005314$

$\hat{Y}(1550)=6.525$

$V_{YX}=2.422$ $\Sigma x=1.338 \times 10^7$

conservative estimate of $\hat{\sigma}_y = \sqrt{V_{YX}\left(\frac{1}{n}+1+\frac{(x-\bar{x})^2}{\Sigma x}\right)}$

less conservative estimate $=\sqrt{V_{YX}}$

$$\hat{\sigma}_y = \sqrt{2.422\left(\frac{1}{67}+1+\frac{(1550-1002)^2}{1.338 \times 10^7}\right)} = 1.585$$

$$\hat{\sigma}_{\bar{y}} = \sqrt{2.422\left(\frac{1}{67}+\frac{(1550-1002)^2}{1.338 \times 10^7}\right)} = 0.301$$

[PCB],1550,high = exp(6.525 + .301 +.7925) = 2036 ppm (+35%)
[PCB],1550,best = exp(6.525 + .7925) = 1506 ppm
[PCB],1550,low = exp(6.525 - .301 +.7925) = 1115 ppm (-26%)

US 51466

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

UNITED STATES OF AMERICA, Plaintiff, v. OUTBOARD MARINE CORPORATION, Defendant, Third-Party Plaintiff, and Cross-Claim Defendant, and MONSANTO COMPANY, Third-Party Defendant and Cross-Claim Plaintiff.	No. 78 C 1004 Judge Susan Getzendanner

NOTICE OF FILING

TO: See Attached List.

PLEASE TAKE NOTICE that on Friday, February 4, 1983, the undersigned filed with the Clerk of this Court,

PLAINTIFF'S RESPONSE TO THIRD PARTY DEFENDANT MONSANTO COMPANY'S FOURTH SET OF REQUESTS FOR ADMISSION TO PLAINTIFF UNITED STATES

service of which is being made upon you.

DAN K. WEBB
United States Attorney

BY: ______________________________
JAMES T. HYNES
Assistant United States Attorney
Attorney for the United States
219 South Dearborn Street
Chicago, Illinois 60604
(312)353-1996

JTH:ejd
02/04/83

AFFIDAVIT OF MAILING

STATE OF ILLINOIS)
) SS
COUNTY OF C O O K)

Elaine J. Davis, being first duly sworn on oath deposes and says that ~~he~~/she is employed in the Office of the United States Attorney for the Northern District of Illinois; that on the 4th day of FEBRUARY, 1983, ~~he~~/she placed a copy of the NOTICE OF FILING,

and PLAINTIFF'S RESPONSE TO THIRD PARTY DEFENDANT MONSANTO COMPANY'S FOURTH SET OR REQUESTS FOR ADMISSION TO PLAINTIFF UNITED STATES

in a Government franked envelope addressed to each of the following named individuals, and caused each envelope to be deposited in the United States mail chute located in the Everett McKinley Dirksen Building, Chicago, Illinois, on said date at the hour of about 5:00 p.m.

SEE ATTACHED LIST.

Elaine J. Davis

SUBSCRIBED and SWORN TO before me this

day of , 1983.

NOTARY PUBLIC

My Commission Expires: ______________

NOTICE TO:

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Elizabeth Stein, Esquire
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Department of Justice
Washington, D.C. 20530

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

UNITED STATES OF AMERICA, Plaintiff, v. OUTBOARD MARINE CORPORATION, Defendant, Third-Party Plaintiff, and Cross-Claim Defendant, and MONSANTO COMPANY, Third-Party Defendant and Cross-Claim Plaintiff.	)	No. 78 C 1004 Judge Susan Getzendanner

PLAINTIFF'S RESPONSE TO THIRD PARTY DEFENDANT MONSANTO COMPANY'S FOURTH SET OF REQUESTS FOR ADMISSION TO PLAINTIFF UNITED STATES

In accordance with Rule 36 of the Federal Rules of Civil Procedure, plaintiff United States hereby responds to third party defendant Monsanto Company's Requests to Admit as follows:

REQUEST NO. 1

Dr. David Weininger is employed by USEPA.

RESPONSE:

Request No. 1 is admitted.

REQUEST NO. 2:

At the request of USEPA, Dr. Weininger reviewed the Thomann Report for scientific validity and commented about it.

RESPONSE:

Request No. 2 is admitted.

REQUEST NO. 3:

Dr. Weininger reviewed the Thomann Report and made comments about it in his capacity as an EPA employee.

RESPONSE:

Request No. 3 is admitted.

REQUEST NO. 4:

Dr. Weininger's comments about the Thomann Report are set forth in Exhibit A hereto.

RESPONSE:

Request No. 4 is admitted.

REQUEST NO. 5:

In March, 1981, Mr. Edward H. Brown, Jr. was an employee of the U.S. Fish & Wildlife Service. He was employed at the Great Lakes Fishery Laboratory in Ann Arbor, Michigan.

RESPONSE:

Request No. 5 is admitted.

REQUEST NO. 6:

At this time Dr. Brown was generally familiar with information and studies concerning the Lake Trout in Lake Michigan.

RESPONSE:

Request No. 6 is admitted.

REQUEST NO. 7:

In March, 1981, Mr. Brown authored a paper entitled "A Background Discussion of the Lake Michigan Committee's Goal for Lake Trout Rehabilitation." This paper was presented at the Great Lakes Fishery Commission, Lake Michigan Committee Meeting in Milwaukee, Wisconsin.

RESPONSE:

Request No. 7 is admitted.

REQUEST NO. 8:

Mr. Brown presented this paper in his capacity as an employee of the U.S. Fish & Wildlife Service.

RESPONSE:

Request No. 8 is admitted.

REQUEST NO. 9:

Larry Kamer has made no formal survey to determine the level of public interest regarding the presence of PCB's in Waukegan Harbor or North Ditch, or on the property of OMC.

RESPONSE:

Request No. 9 is admitted.

REQUEST NO. 10:

Any testimony of Larry Kamer regarding any alleged "restricted use and enjoyment" of Waukegan Harbor by the public is not based on any scientifically designed and executed survey or study.

RESPONSE:

Request No. 10 is admitted.

REQUEST NO. 11:

Any testimony of Larry Kamer regarding any alleged "restricted use and enjoyment" of Waukegan Harbor by the public is not based on any study or survey of any statistically representative sample of the public.

RESPONSE:

Request No. 11 is admitted.

REQUEST NO. 12:

Any testimony of Larry Kamer regarding any alleged "restricted use and enjoyment" of Waukegan Harbor by the public is not based on information obtained by using a standard questionnaire or list of questions.

RESPONSE:

Request No. 12 is admitted.

REQUEST NO. 13:

Any testimony of Larry Kamer regarding any alleged "restricted use and enjoyment" of Waukegan Harbor by the public is not based on any information or observations that Mr. Kamer regularly, systematically and completely recorded.

RESPONSE:

Request No. 13 is admitted.

REQUEST NO. 14:

Mr. Kamer has no records that identify the persons with whom he had discussions regarding their "use and enjoyment" of Waukegan Harbor.

RESPONSE:

Request No. 14 is admitted.

REQUEST NO. 15:

Mr. Kamer made no contemporaneous notes or records regarding any of his observations relating to the "use and enjoyment" of Waukegan Harbor by the public.

RESPONSE:

Request NO. 15 is admitted.

REQUEST NO. 16:

Mr. Kamer made no contemporaneous notes or records regarding any of his observations relating to the "use and enjoyment" of Waukegan Harbor by the public.

RESPONSE:

Request No. 16 is admitted.

REQUEST NO. 17:

Mr. Kamer has no contemporaneous notes or records regarding any conversations or discussions with people who regularly use or have used Waukegan Harbor concerning their use and enjoyment of the Harbor.

RESPONSE:

Request No. 17 is admitted.

DAN K. WEBB
United States Attorney

BY: ______________________________
JAMES T. HYNES
Assistant United States Attorney
Attorney for the United States
219 South Dearborn Street
Chicago, Illinois 60604
(312) 353-1996

Dated: February 4, 1983

JTH:ejd

GLFC
Lake Michigan Committee Meeting
March 12, 1981
Agenda Item 9.a

A Background Discussion of the Lake Michigan Committee's Goal for Lake Trout Rehabilitation

Report for the Lake Michigan Lake Trout Technical Committee[1]

Edward H. Brown, Jr., Chairman
U.S. Fish and Wildlife Service
Great Lakes Fishery Laboratory
Ann Arbor, Michigan

This report is presented in response to charges given the Lake Trout Technical committee at the 1980 Annual Meeting of the Lake Michigan Committee: (1) to establish the magnitude of current lake trout withdrawal from Lake Michigan by all user groups; and (2) to prepare a discussion paper for the 1981 meeting on the Lake Committee's goal for lake trout rehabilitation. The report reviews and synthesizes pertinent background information on lake trout which the technical group can use as it completes steps for implementing the Lake Committee's goal. At this stage, however, the contents of the paper are still subject to overall review and do not necessarily represent a consensus of the Technical Committee members or their agencies.

Introduction

As a basis for this discussion, the Lake Michigan Committee's general goal for lake trout rehabilitation is defined tentatively as follows: to reestablish and maintain the most stable and productive self-reproducing lake trout population(s) possible within limits of (1) Lake Michigan's altered carrying capacity for the species, (2) funds available for interim hatchery production and experimental management, and (3) existing jurisdictional and legal constraints. Such realities as widespread sport fisheries, Indian Treaty fishing, and insignificant natural reproduction by planted fish have led a few to question whether such a goal is practical or even desirable in the face of heavy user demand. The Great Lakes Fishery Commission, nevertheless, strongly endorses "self-sustaining stocks" as a major objective of the rehabilitation program, although it has acknowledged the importance of fisheries for planted

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[1] Presented at: Great Lakes Fishery Commission
Lake Michigan Committee Meeting
Milwaukee, Wisconsin
March 11, 1981

lake trout and the temporary necessity of selecting planting sites to facilitate harvest in some areas for social and economic reasons (Great Lakes Fishery Commission, policy statement adopted June 14, 1976). The degree to which this expedient option of put-and-take fishing continues to be implemented, however, is as important a consideration as lake trout biology in projecting the attainable size, biological characteristics, and dynamics of rehabilitated stocks.

The Native Trout: A Lake Michigan Benchmark

The size and productivity of populations of native lake trout in the pre-lamprey era, as judged mainly from commercial fishing records, are a logical point of departure for projecting the maximum size and potential yields of self-sustaining populations.

Average annual commercial production of the native trout declined progressively from 3,700 metric tons (t) (8.2 million lbs.) in 1890-1911 to 2,600 t (5.7 million lbs.) in 1927-44, shortly before the trout were driven to extinction by the sea lamprey (Baldwin et al. 1979). Smith (1968) concluded that the decline in lake trout production early in this century resulted from restabilization that normally occurs when a fishery is imposed on a virgin population, and that the stocks were not over-exploited. But he also concluded that a sharp increase in fishing intensity and production in Illinois waters in 1940-44 may have been sufficient to weaken the stocks if they were already being fished near the point of maximum sustained yield in other jurisdictions. Van Oosten (1949) and Wells and McLain (1973) drew the opposite conclusion in concurring that the gradual decrease in lake trout production during 1893-1938 was due to excessive exploitation. Their opinions that overfishing occurred over the years in some areas are supported by a recent review of information on the early fisheries (Brown et al., In press) which suggested that some stocks were depleted before the 1930s. Hile et al. (1951) offered no explanation for the long term drop in productivity, but concluded that lake trout were not overfished, at least in State of Michigan waters, during the final period of steady yields and apparent population stability (i.e., abundance) from 1929 to 1943.

If, as Smith (1968) proposed, the native trout were fished near the point of maximum sustained yield in 1927-1944, the average annual commercial catch ($\bar{c}$) and the exploitation rate (u) would provide a rough estimate of the standing stock ($\bar{S}$) that must have been present to sustain the maximum-yield fishery ($\bar{S} = \bar{c}/u$). Although the rate of exploitation was never determined during the early fishery, Silliman (1969) has since obtained a "fairly good" simulation fit by analog computer to the reported yields in State of Michigan Waters (Hile et al. 1951), using instantaneous fishing (F) and natural (M) mortality rates of 0.50 (average) and 0.20, respectively. The average 1927-44 yield of 2,600 t divided by a u of 0.36, computed with Silliman's provisional mortality rates, gives a fishable stock for that period of 7,200 t (15.9 million lbs.). On the basis of Lake Michigan's total surface area of 5.73 million hectares (14.3 million acres), the 1927-44 average estimated standing stock and reported yield amount to 2.73 and 0.45 kg/ha, respectively. The actual yield per hectare is close to the upper limit of 0.5 deduced by Healey (1978) for stocks under sustained-yield fishing in Canada and the U.S.

Moreover, the sum of Silliman's instantaneous rates (Z = 0.70) is almost equivalent to an annual mortality rate (A) of 0.50 proposed by Healey (1978) as the highest mortality rate that stable lake trout populations can withstand.

The average production of 1927-44 (2,600 t) is therefore the most realistic upper limit available of what future stocks can be expected to sustain, before allowance is made for the altered ecological conditions of the lake today and the possible lack of essential adaptive characteristics in present strains of lake trout (Brown et al., In press).

Carrying Capacity of Lake Michigan for Lake Trout

Lake Michigan's carrying capacity for lake trout has been modified since 1927-44 by at least three ecological changes: (1) the shift in the primary forage species from ciscoes to alewives, (2) the development of sizable hatchery-maintained or partly-maintained populations of Pacific salmon and other species of trout, and (3) the persistence of residual populations of sea lampreys that now exert a small but additional mortality on the trout (Wells 1980). Full realization of the modified carrying capacity will eventually be determined by whether successfully reestablished trout can adapt to the lake's different physiographic areas as well as their native predecessors did.

Changes in the Forage Base

Since much uncertainty (due to limitations in sampling technology) persists about the size of the present forage base and less is known about the size and dynamics of earlier forage stocks, it is impossible to accurately estimate changes in the amounts of forage available to lake trout and other salmonids since 1927-44. One can only speculate about possible differences on the basis of limited existing data and assumptions substituted for essential statistics (e.g., mortality rates and/or exploitation rates for different ages or life stages of the species in each period).

Smith (1968) proposed that the deepwater and shallow-water complex of ciscoes (i.e., several species of "chubs" and the lake herring), on which the native lake trout foraged, used the invertebrate food of the lake more "efficiently" than the alewife which largely replaced the ciscoes by the 1970s. This idea is compatible with observations on a number of small lakes and reservoirs by Carlander (1955) showing that the standing crop of a body of water increases roughly (i.e., variation about regression was high) as the number of species of fish increases. The idea espoused by Smith of a more productive forage base before the sea lamprey invasion of Lake Michigan is also reasonable in regard to energy conversion into food directly consumable by humans (i.e., ciscoes and herring), and it may well hold in regard to a more stable supply of forage for the once abundant and now extinct deepwater form(s) of lake trout (Brown et al., In press). On the other hand, the alewife is lower on the food chain than coregonines and may now provide more forage in both the benthic and midwater strata of the shallow area around the circumference of the lake, as well as in the deeper areas in the winter. This forage is the mainstay of comparatively more pelagic salmon and steelheads, as well as for brown trout and for stocked lake trout, which occupy depths of water somewhat similar to those of the native reef or shallow-water form(s) of the past.

Since 1977, Lake Michigan's forage base has actually been reverting to proportionately more coregonines, as indicated by steady and marked improvement in the production (i.e., year class strength) of young bloaters, but this change has not been detected yet in the food habits of salmonids. The severely depleted bloater stocks were protected by a lakewide ban on commercial fishing for several years in the late 1970s and are still protected in State of Michigan waters where their improvement has been the most substantial. The ultimate extent of the bloater increase and how much it will affect alewives and thence salmonids is not known.

The estimated benthic biomass of alewives (≥ age I), unadjusted to include those in midwater and those that evade bottom trawls, varied between 44.9 and 114.4 metric tons (109 to 252 million lbs.) during fall 1973-1980 (Fig. 1), after recovering from the heavy lakewide die-off in early 1967. The magnitude (> 2x) of these annual biomass changes suggests that size of the alewife population(s) is still being controlled to a considerable degree by factors other than predation. The weakest year class of 1969-74, gauged by its contribution to the adult stock, was produced in 1972, the year with the lowest mean summer and fall water temperatures in east-central Lake Michigan (GLFL unpublished data). The survival, especially of young alewives, may also have been lowered by low-temperature stress during severe winters, beginning with that of 1976-77, when the entire lake froze over for a short period in January. This reduction in abundance of alewives may also have reduced some of the competitive pressure on bloaters and thereby contributed indirectly with the ban on fishing to the recent upsurge in bloater abundance.

Estimation of the entire standing stock of alewives in the lake and their biological production is the most difficult problem in determining if and when the available forage has begun to limit further increases in the populations of lake trout and other salmonids. To achieve this feat, the benthic biomass must be augmented by at least two levels of expansion; first to include the biomass of partially recruited younger age groups, and then the pelagic fraction of the population and the part of the benthic population that evades or escapes the trawl. A general idea of the differences in size between the benthic (unadjusted) and total alewife biomasses and the production of each is given by an exploratory expansion of the average fall 1978-79 benthic estimates, using a number of partly subjective factors and statistics (Table 1). The provisional total biomass of age I-VIII fish so obtained was 5.2 times greater than the benthic estimate, and production for those age groups was 5.9 times greater.

Because of species-specific and life-stage specific differences in distribution of the prey and predators, all of the alewife production in a given period is, of course, never available to any one predator species. During the period of thermal stratification, adult lake trout occupy a limited thermal zone near the lake bottom, and immature trout are found at greater depths; whereas the other salmonids have higher temperature preferences (Stewart 1980) and, to varying degrees, are more pelagic. It is generally conceded that lake trout alone could not bring about a collapse of the alewife population because the differing spatial distributions provide some life stages of alewives with seasonal refuges from the trout.

Lake Trout as Part of a New Array of Salmonid Predators, and Their Relations to the Forage Base

Today's population of hatchery-reared lake trout in Lake Michigan, estimated at 2.7 million fish weighing 1,600 t (3.5 million lbs.) in January 1979 (GLFL unpublished data), is but a modest part of the combined standing stocks of 7 salmonid species, having a total fishable biomass that may well exceed the 7,200 t (15.9 million lbs.) projected for native lake trout of 1927-44. Moreover, due to gradual increases in the numbers of other salmonids stocked since the mid-1960s, lake trout only compose about 20% of the young salmonids now being planted annually in Lake Michigan (Table 2).

Despite recent oscillations in alewife abundance, there is yet no evidence that forage has been in seriously short supply for the stocked lake trout. Indeed, it is conservatively estimated that these trout consumed 1,900 t (4.2 million lbs.) of alewives during fall 1978-79, 85% of which represented age II and older fish equal to 1.4% of the projected (provisional) annual production of alewives in those age groups. The growth rate of the stocked trout apparently has declined since the 1960s, as one might expect, but they are still growing faster than native fish taken in the commercial fishery in 1947 (Fig. 2 and GLFL unpublished data).

Although it is recognized that the standing "crop" of a fish species will be less in the presence of other species at the same trophic level than by itself (Carlander 1955), it is extremely difficult to predict how much more the combined standing stocks of lake trout could be increased while the present stocks of salmon and other trout are being maintained. This question would be even more difficult to address if the lake trout were reproducing and successfully replenishing themselves. The native trout had no large competitors except for smaller populations of burbot in the lake proper and perhaps the walleye in Green Bay. Steelhead and brown trout populations were probably insignificant in the inshore waters as compared to the present, judging by the fact that few were planted during 1915-1950 (Wells and McLain 1973).

Each of the present species of trout and salmon occupy a distinct niche, of course, with different temperature, space, and food requirements as noted above. The food requirements of adult lake trout would appear to overlap most broadly with those of the chinook salmon as indicated by a predominance of adult alewives in the diet of each in the southern half of the lake (Stewart 1980). Moreover, potential competition for food and space is not likely to be seasonally reduced because neither migrates to a distant region of the lake to winter like the coho. The present tendency among management agencies to stock more chinook and proportionately fewer cohos (Table 2) would therefore be expected to have a greater effect on the lake's carrying capacity for lake trout than a stocking strategy that emphasizes coho salmon might have.

Effects of Sea Lamprey Predation on Potential Yields of Lake Trout

Technically, sea lampreys may be more a resource exploiter than a determinant of carrying capacity, but nonetheless the residual populations continue to impose a moderate to small additional component of natural mortality on lake trout. This continuing attrition will surely reduce future yields that self-sustaining stocks of lake trout might otherwise theoretically sustain. Sea lamprey wounding rates ranged from 0.0 to 4.9% among three size classes of lake trout in 4 regions of the lake in 1979 and 1980 (Wells 1980). In most years of record during 1971-80, the wounding rates were less than 5%, except for those of larger trout in northern Wisconsin waters, which dropped below 5% in 1980, for the first time in 8 years. Wells (1980) computed tentative instantaneous sea lamprey-induced annual mortality rates of 0.05 and 0.31 for southeastern and northwestern waters of Lake Michigan respectively, using a regression model developed by Pycha (1980) for Lake Superior lake trout. Wells combined these values with Pycha's 0.26 estimate of natural mortality from other causes to estimate total natural mortality rates (M) of 0.31 and 0.57 in those respective geographical areas. The actual rates are somewhat higher in Lake Michigan if, as Wells believes, a more conservative procedure was used to count the wounds on lake trout there than in Lake Superior. Rybicki and Keller (1978) obtained a slightly lower M of 0.28 by an independent regression method for lake trout in State of Michigan waters.

Toward a Realistic Goal

After considering the widespread lack of reproductive success of planted lake trout in Lake Michigan and some of the factors reviewed in this report that have affected carrying capacity, the Lake Trout Technical Committee and other attendees at the 1980 Michigan Committee Meeting recommended that a self-sustaining lake trout population capable of producing an annual sustained yield of 1,134 t (2.5 million lbs.) was a realistic quantitative target for rehabilitation efforts. This targeted yield of slightly less than 1/2 that of 1927-44 is perhaps a reasonable first approximation which can be adjusted upward or downward as new intelligence is provided by experimental management.

A lake trout stock capable of providing such a sustained yield would require entry to the pre-recruit phase of several million yearling trout annually, depending on the rate of fishing (F) that would not increase total mortality above a biologically reasonable level--ideally somewhat less than the probable maximum withstandable rate (Healey 1978) of 0.50 (Z = 0.69). The Lake Ontario Lake Trout Subcommittee (1981) has examined equilibrium yields (Ricker 1975) under a number of mortality rate scenarios and estimated that 2 and 3 million yearlings would be required for a rehabilitated stock in that lake to sustain a recommended yield of 453.6 t (1 million lbs.) at annual mortality rates of 0.50 and 0.40 respectively. They also estimated that at an annual mortality rate of 0.45, the average female trout would survive 1.21 years (Abrosov's t) beyond the age at first maturity. The Lake Ontario yield calculations were predicated on an instantaneous natural mortality rate (M) of 0.35, which is somewhat higher than that of 1980 in Lake Michigan because of higher sea-lamprey predation rates on the Lake Ontario trout. The composite growth rate that they employed is roughly comparable to the present high rate of planted trout in Lake Michigan (Fig. 2). As a self-sustaining population increases in size over that of the present planted trout, however, growth would decline some and the number of pre-recruits concommitant with any recommended yield would also increase.

The Rehabilitation Time-Table

Judging by the rate at which "stocks" of naturally produced lake trout have evolved in Lake Superior since rehabilitation was begun there in the early 1960s, a considerable but indefinite amount of time will lapse before stock composition in Lake Michigan reaches 50% naturally produced fish. This milestone has been reached in the Munising-Grand Marais area of Lake Superior, but there is evidence of set-backs in some areas because of inadequate control of exploitation (R. Pycha, Great Lakes Fishery Laboratory unpublished report). The problem of excessive lake trout extractions is no less serious in Lake michigan, where a surprisingly intensive sport fishery developed in southeastern and east-central waters in the 1970s (Rybicki and Keller 1978), and an Indian-Treaty commercial fishery recently began making large catches to the northeast. Significant sport fisheries are also operating now in all of the other jurisdictions. It is estimated conservatively (the incidental catch record is incomplete) that in 1979, the last year with fairly complete and accurate catch records from all user groups, the various fisheries had a combined catch of 279,000 stocked lake trout, possibly weighing as much as 632.3 t (1.4 million lbs.) (Table 3). Because of weather conditions that affected fishing, however, the 1979 catch of trout by the sport fishery was below the average of recent years. Preliminary reports from Indiana and Wisconsin indicate that the lakewide sport catch was much higher in 1980.

As an alternative to lakewide restrictions on lake trout fishing, an expanded system of lake trout refuges may be necessary to provide epi-centers of lake trout abundance. Such a year-around refuge was established in the Gull Island shoal area of western Lake Superior in 1976, following a 50% reduction of the spawning stock between 1974 and in 1975 (R. Pycha, GLFL unpublished report). Two years after the refuge was formed, the spawning population on Gull Island Shoal had rebounded to the 1974 level of abundance. A refuge limited to certain depths of water was also established in Wisconsin waters of Lake Michigan in 1980 to protect an experimental mid-lake plant of Green Lake strain lake trout from gillnets fished for chubs, and small refuges have been established in northern Lakes Michigan and Huron in connection with the regulation of Indian Treaty fishing.

In addition to greatly reducing exploitation, planting densities for lake trout greater than the lakewide average of 0.41/hectare (0.16/acre) since 1965 may be essential to overcome the site-specific reproductive inefficiency of the hatchery-reared trout. This change is suggested by successful reproduction in an Ontario lake of lake trout planted at much higher densities than those stocked in Lake Michigan since 1965 (Olver and Lewis 1977). Other remedies to overcome the reproductive inefficiency of the planted trout and environmental and genetic factors that may be contributing to such inefficiency were discussed in a paper for the STOCS Symposium, and need not be repeated here (Brown et al., In press).

The rapidity with which these biological and institutional impediments are addressed will determine if and how soon the lake trout resource in Lake Michigan transforms from a hatchery-dependent, and therefore a transient entity, to a complex of self-sustaining stocks able to produce the forementioned harvestable surplus as projected by the Lake Michigan Committee.

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Table 1. Provisional estimates of mean biomass and production[a] of Lake Michigan alewives during October-November 1978-1979, as computed by three stages of adjustment of lakewide bottom-trawl catches.

Stage of trawl-catch adjustment	Age	Biomass		Production		Prod./Biomass X 100
		Metric tons	Pounds X 10^3	Metric tons	Pounds X 10^3	
Trawl catch, area expansion[b]	0-I	2,800	6,200	6,300	13,900	225
	I-VIII	78,600	173,000	19,800	43,700	25
	0-VIII	81,400	179,200	26,100	57,600	32
awl catch, area exp., age adjustment	0-I	78,600	173,000	68,900	152,000	88
	I-VIII	137,000	302,000	39,300	86,600	29
	0-VIII	215,600	475,000	138,200	238,600	50
Trawl catch, area exp., age adjustment X 3[c]	0-I	236,000	520,000	207,000	456,000	88
	I-VIII	411,000	906,000	118,000	260,000	29
	0-VIII	647,000	1,426.000	415,000	716,000	50

[a] Mean biomass ($\bar{B}$) times instantaneous growth rate (G).

[b] Minimum biomass of Hatch et al. (In press).

[c] The factor 3 is used to adjust for the pelagic part of the stock, on the basis of, but somewhat more conservatively than, the average ratio of the catch per unit volume trawled by a high-rise trawl to that of the standard 39-foot trawl (R. Argyle, Great Lakes Fishery Laboratory, unpublished data).

Table 2. Numbers (thousands) of lake trout and other salmonids planted in Lake Michigan by all jurisdictions combined, 1966 - 1978 a/.

	Trout					Salmon				
Year	lake b/	steelhead	brown	brook	total	coho	chinook	Atlantic	total	grand total
1966	1717	76	43	49	1885	660	-	-	660	2545
1967	2424	95	63	34	2616	1732	802	-	2534	5150
1968	1876	458	205	49	2588	1201	687	-	1888	4476
1969	2001	439	171	74	2685	3280	718	-	3998	6683
1970	1960	642	156	120	2878	3543	1904	-	5447	8325
1971	2343	1252	788	130	4513	2751	2317	-	5068	9581
1972	2926	1238	837	97	5098	2623	2139	10	4772	9870
1973	2509	2609	1788	50	6956	2518	2986	15	5519	12475
1974	2397	2054	686	85	5222	3231	3578	22	6831	12053
1975	2577	1568	665	110	4420	2505	4280	22	6807	11227
1976	2624	1827	1251	79	5781	3196	3403	21	6620	12401
1977	2368	1312	1180	643	5503	3087	2977	19	6083	11586
1978	2589	1933	1503	248	6273	2685	5365	46	8096	14369
1979	2497	2589	1228	196	6510	4044	[illegible]	170	9198	[illegible]

a/ Statistics for lake trout and salmon are from various annual reports of the Great Lakes Fishery Commission; those for steelhead and brown trout before 1975 and brook trout before 1976 were compiled by J. Parsons (Great Lakes Fishery Laboratory unpublished report).

b/ In 1965 and 1979 respectively, 1274 and 2497 thousand lake trout were planted, but planting records were not available for other species.

Table 3. The 1979 estimated catch of lake trout in Lake Michigan, by jurisdiction and statistical district: user-group portions were obtained from direct catch reports, or were estimated from creel censuses and mail surveys.

Jurisdiction	Statistical District	Fishery: Sport	Fishery: Assess-ment	Fishery: Commer-cial	Fishery: Indian-treaty	All Fisheries
Michigan	MM-1	320	31	-	4,430	4,781
	2	785	-	-	6,823	7,608
	3	8,378	108	180	75,220	83,886
	4	8,436	274	-	15,309	24,019
	5	15,079	935	-	5,709	21,723
	6	12,684	382	-	515	13,581
	7	24,553	-	-	19	24,572
	8	24,756	1,094	-	-	25,850
	1-8	95,621	2,824	180	108,025	206,650
Wisconsin	WM-1	-	-	-	-	-
	2	-	-	-	-	-
	3	-	1,486	-	-	1,486
	4	-	-	-	-	-
	5	-	769	-	-	769
	6	-	-	-	-	-
	1-6	23,594[a]	2,255	-	-	25,849
Illinois	ILL	8,948	1,837	33,620[b]	-	44,405
Indiana	IND	1,387	580	-	-	1,967
All Jurisdictions		129,550	7,496	33,800	108,025	278,871[c]

[a] Not reported by district.

[b] Expanded on basis of four onboard checks of the percentage of the incidental catch that could not be released alive.

[c] X 5 lb/fish = 1,394,000 lb.

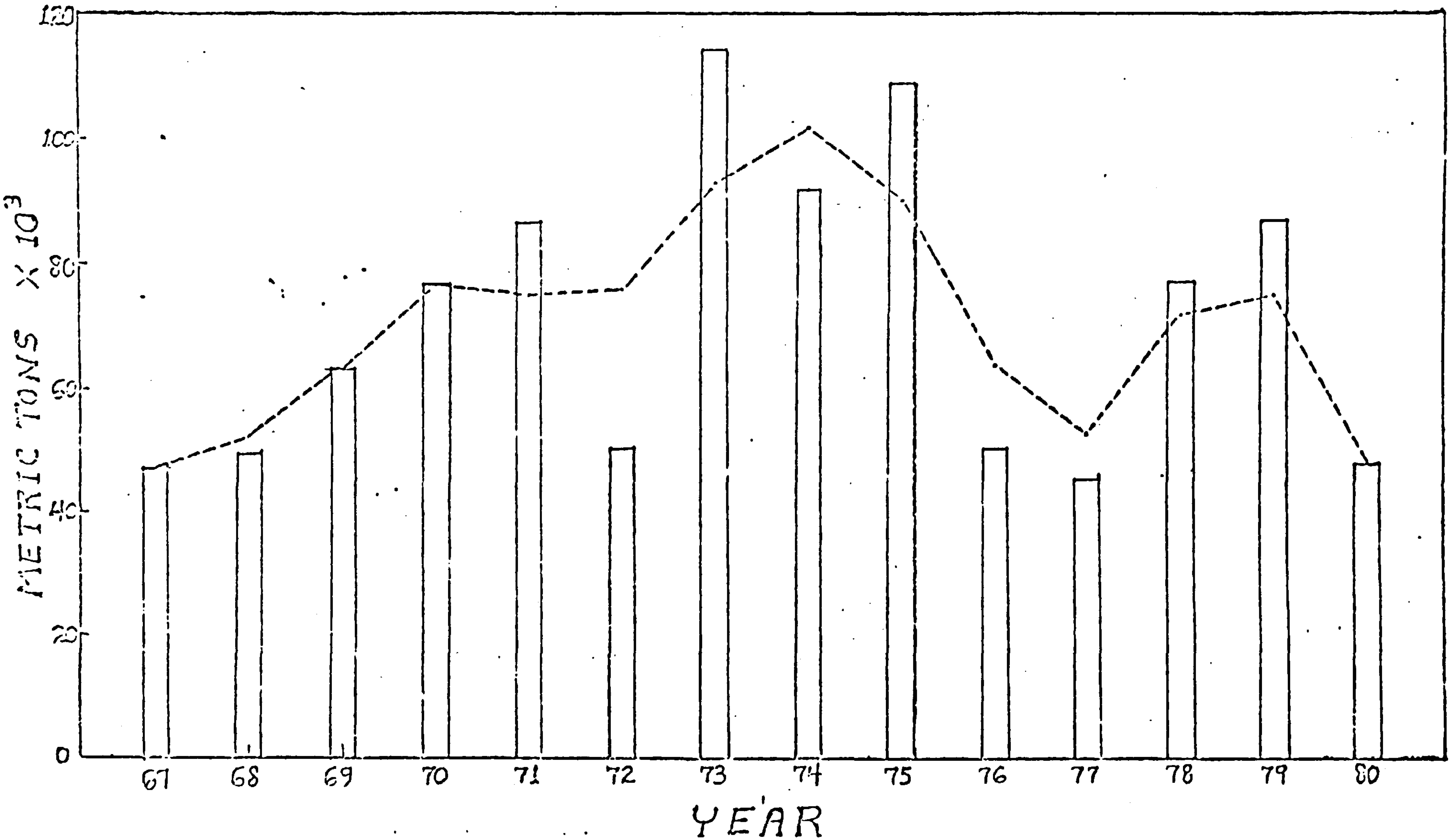

Figure 1. Estimated alewife biomass (≥ age I) available to bottom trawls at 9- to 100-m depths in Lake Michiga October-November 1967-80, unadjusted for trawl efficiency (Data from Hatch et al. In press, and Wells and Hatch 1981): points on the hypothetical trend line represent two running averages of two.

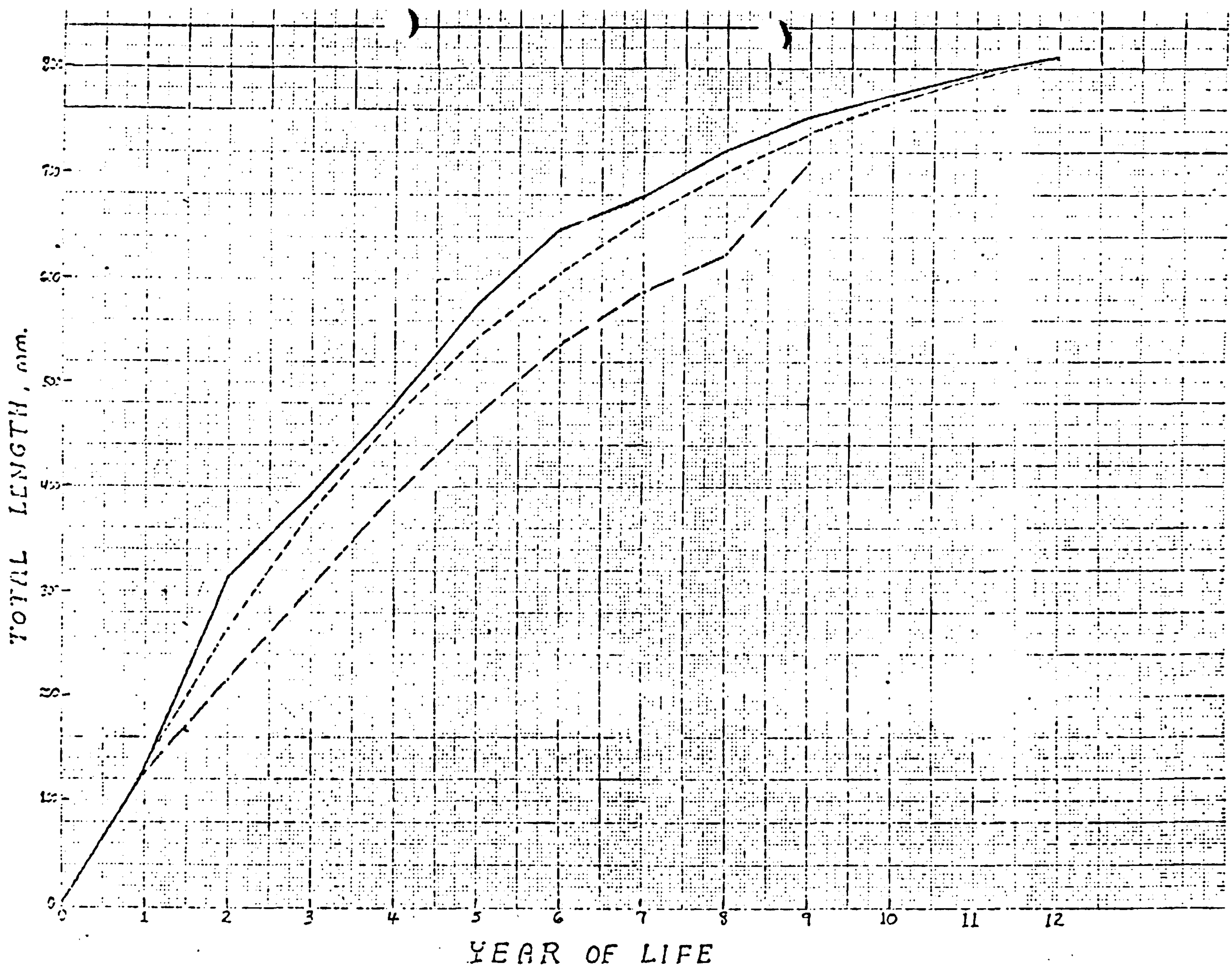

Figure 2. Average total length of Lake Michigan lake trout for successive years of life: the solid line represents lakewide spring collections from graded-mesh (2 1/2-6 inch) gillnets of cooperating agencies, 1976-79; the short dashes, a von Bertalanffy fit to cohort mean lengths from bottom and highrise trawls (spring) and graded-mesh gill [illegible]s (October), Saugatuck, Michi[illegible], 1970s; and the long dashes, a collection [illegible] commercial gillnets, Montag[illegible], Michigan, October 1947 (Van Oosten 19[illegible]).